ISSN 0040-6015, Thermal Engineering, 2011, Vol. 58, No. 1, pp. 8–11. © Pleiades Publishing, Inc., 2011.
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The T-120/130-12.8 and PT-100/130-12.8/1.0 Cogeneration Steam Turbines Produced by the Ural Turbine Works for Replacing Turbines of the T-100 Family

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Abstract—The basic design features and technical characteristics of the turbines installed on the foundation of the T-100 family turbines are presented.

DOI: 10.1134/S0040601511010022

In the period from the 1950s to 1970s, the OAO Turbine Engine Works, presently the ZAO Ural Turbine Works (UTZ), produced different versions of cogeneration steam turbines with a rated capacity of 100 MW for the live steam parameters 12.8 MPa and 555°C [1]. The majority of them have already worked out their service life; therefore, the question of replacing them is becoming increasingly more pressing despite the existing operational practices of extending the service life of turbine assemblies made of heat-resistant steels.

In recent years, several projects of cogeneration turbines with improved economic indicators have been developed at UTZ, and part of them have already been brought to a level of serially produced equipment, including a two-cylinder steam turbine with heating extractions of steam with a rated capacity of 115 MW for the initial steam conditions 12.8 MPa and 555°C (the Tp-115/125-130-1 turbine) and two-cylinder turbines with a rated capacity of 90 MW having process and heating steam extractions for the initial steam conditions 12.8 MPa and 555°C (the PT-90/120-130/10-1 and PT-90/125-13/10-2 turbines); the majority of them are in operation at Chinese cogeneration stations (CSs) and find use at CSs in Russia and CIS countries [2]. However, these turbines cannot be installed on the foundation of a three-cylinder turbine belonging to the family of T-100 turbines; therefore, UTZ specialists have developed projects of three-cylinder turbines for the live steam parameters 12.8 MPa and 555°C, which incorporated advanced solutions aimed at achieving better indicators of efficiency, reliability, and maneuverability. In view of the fact that the previous turbines were installed at CSs of a purely heating type, the designers of new turbines solved the question of making them suitable for supplying process steam to the CSs, the use of which makes it possible to do without steam from the reducing and cooling installation (RCI) that was applied for these purposes. Below, the design features and main characteristics of the new turbines are considered.

THE T-120/130-12.8 TURBINE

The T-120/130-12.8 turbine (Fig. 1) is a three-cylinder machine containing a high-pressure, an intermediate-pressure, and a low-pressure cylinder (HPC, IPC, and LPC). Live steam is admitted to the single-shell HPC from a standalone stop valve to four unbalanced control valves made with perforation, the use of which prevents them from being exposed to pulsations of supplied steam occurring in the operating modes with partially opened valves, thus excluding the possibility of breaking their stems [3].

The HPC flow path consists of a single-bucket control stage with a mean diameter of 1100 mm, which is fully standardized with the similar stage used in the HPC of a T-250/300-240 turbine, and ten pressure stages. The rotor blades of these stages have a root diameter of 800 mm. The use of a single-bucket control stage instead of a two-bucket one (that was used in the turbines that have worked out their service life) and pressure-stage guide vanes having profiles more advanced in aerodynamic respect made it possible to increase the HPC efficiency by around 3.5%. Cellular seals have been used as shroud, diaphragm, and end seals, the use of which allows the HPC efficiency to be additionally increased by 1.0–1.2%. The stages are made with superimposed shrouds. The possibility of using all-milled shrouds is being considered. The new HPC is fully installed on the pedestal of its predecessor. The disks of the HPC stages are forged together with the shaft.

Spent steam from the HPC is directed to the IPC, the steam admission part of which has a design more advanced in the aerodynamic respect. The flow path

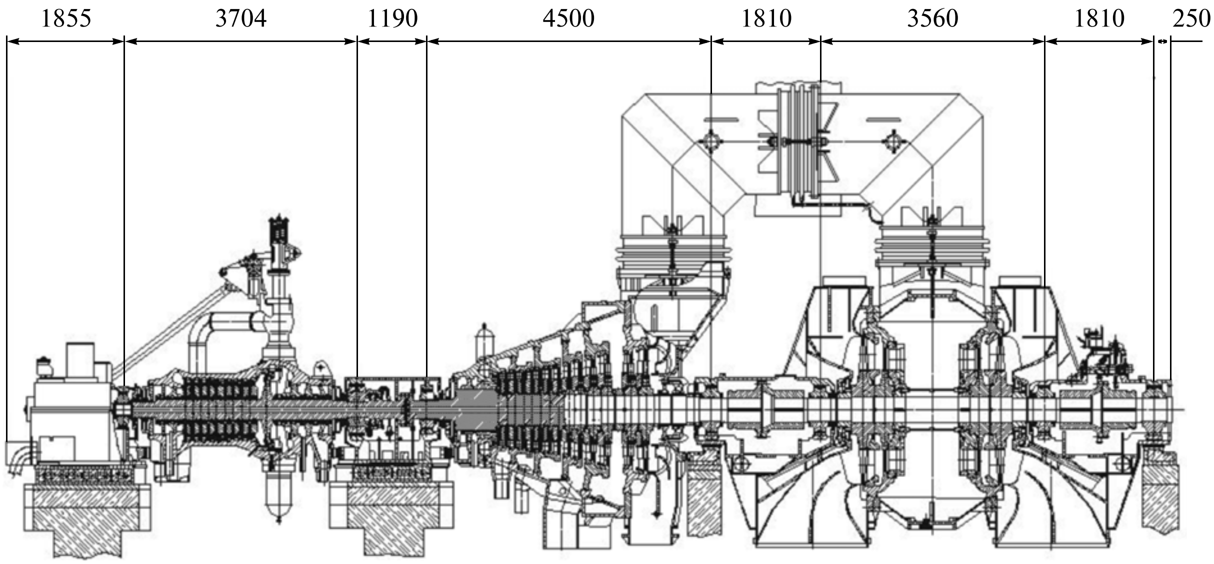

Fig. 1. The T-120/130-12.8 steam turbine.

consists of 14 pressure stages and the disks of the first eight stages are forged together with the shaft. The rotor blades of these stages have a root diameter of 1000 mm. These stages are made with high-efficient axial-radial shroud seals [4], which undergo almost no wear during operation due to large (up to 4.0–4.5 mm) radial gaps.

The first eight stages (stages 11–18) are made with cellular diaphragm seals, and the IPC end seals are also made with the use of cellular seals. Since the IPC operates with an increased steam flowrate, stages 11–13 are made with larger outlet areas, a feature that helps to obtain lower pressure downstream of the IPC, keep its efficiency at a fairly high level, decrease the temperature of feedwater, and, as a consequence, decrease the flowrate of steam extracted for the last high-pressure heater (HPH), the heating medium to which is supplied from the HPC-IPC receiver, which is connected with increasing the turbine capacity. Stages 15, 20, and 22 are made with new profiles of rotor blades, the use of which allows better reliability of the blade system to be achieved. Steam extractions for the heat exchangers of the regeneration system and for the horizontal delivery-water heaters are taken from the IPC lower half.

The shrunk-on disks are made with end-face keys instead of radial ones to reduce the possibility of corrosion damage to the disks during operation.

The LPC has a two-flow arrangement, and each flow contains a control stage and a pressure stage. The last-stage rotor blades have a height of 550 mm, i.e., the same as in the similar turbine of the previous design, which has been approbated for a long time on a large fleet of turbines operating at variable pressure in the condenser and in a wide variation range of volume steam flowrate. The end seals of the LPC have a cellular design. The IPC-LPC receiver is made with hollow variable vanes for removing moisture from the flow core.

The turbine is furnished with an electrohydraulic control system; it also has a special current pickup device with a grounding circuit, which makes it possible to measure the grounding current.

To meet the needs of CS consumers in process steam, the turbine design incorporates the possibility of extracting up to 70 t/h of steam from the HPC-IPC receiver or from the IPC flow path. The steam extraction pipeline is equipped with a combined protection and control valve (PCV) produced by UTZ, which operates from the turbine control system. The use of this valve makes it possible to operate the turbine with taking steam from this extraction in parallel with other sources of steam supply, e.g., the RCI. Only one of the above-mentioned steam extractions can be used at a time for enabling the PCV to maintain the required pressures in the range of steam flowrates to the turbine from 70 to 100%. The pilot turbine is supposed to be installed at the Tolyatti CS. The question regarding the possibility of using the ejectors, heat exchangers of the regeneration system, and delivery-water heaters installed in the turbine unit that is subject to replacement will be decided after carrying out discussions with the customer and will be reflected in the technical specifications.

The main characteristics of the T-120/130-12.8 turbine are summarized in the table.

Table

Parameter	Type of turbine					
	T-120/130-12.8				PT-100/130-12.8/1.0	
Live steam						
pressure, MPa	12.8					
temperature, °C	555					
flowrate, t/h	520		463		520	476
Operating mode	Rated cogeneration	Cogeneration with process steam extraction	Condensing		Rated cogeneration	Condensing
Process steam extraction						
pressure, MPa						
rated	–	–	–	–	0.98	–
range	–	1.2–1.8	0.5–0.7	–	0.78–1.48	–
extraction location		HPC-IPC receiver	IPC		IPC	
Steam flowrate, t/h						
rated	–	70	70	–	150	–
maximal	–	70	70	–	300	–
Pressure in the upper heating extraction, MPa						
rated	0.098				0.098	–
range	0.059–0.245		–		0.059–0.245	–
Condenser						
heat-transfer surface area, m^2	6200					
water flowrate, m^3/h	16000					
nominal temperature of water, °C	20					
steam pressure, kPa	3.9	3.9	3.9	5.6	3.9	5.7
steam flowrate, t/h	17	17	17	324	17	333
Structure of the regeneration system	3HPH + D + 4LPH				3HPH + D + 4LPH	
Heat load, GJ/h	787	656	643	–	502	–
Electrical capacity, MPa	123.6	114.2	116.5	130	100	130
Heat rate, kJ(kW h)	–	–	–	8880	–	9080

Note: HPH is the high-pressure heater, D is the deaerator, and LPH is the low-pressure heater.

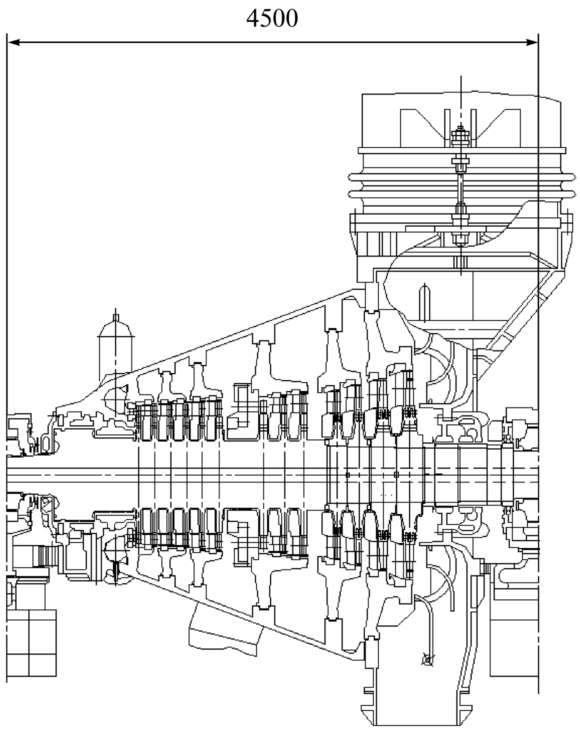

Fig. 2. The IPC of the PT-100/130-12.8/1.0 steam turbine.

THE PT-100/130-12.8/1.0 TURBINE

This turbine is intended for use at CSs that must produce a considerable amount of process steam (from the process extraction) for consumers. The HPC and LPC used in this turbine are fully standardized with those used in the T-120/130-12.8 turbine; the only difference is in the design of the IPC (Fig. 2), which is installed on the pedestal of its predecessor. The flow path consists of 13 stages. Stages 11–16 are fully standardized with the similar stages of the T-120/130-12.8 turbine. Steam for process purposes is extracted after the 16th stage. The control stage (stage 17) is constructed on the basis of the 17th stage of the PT-90 turbine. Stages 18–23 are fully standardized with the similar stages of the PT-90 turbine [2]. The disks of stages 11–21 are forged together with the shaft; the disks of stages 22 and 23 are shrunk-on ones, due to which a new forging of the IPC rotor is used. The disks of these stages are also made with end-face keys.

Since the last stage is made with shorter rotor blades, the IPC is made with a new exhaust part. The design of the cylinder's lower part has also been changed. Despite the fewer number of stages (13 instead of 14), the same number of steam extractions from the cylinder's lower part for the heat exchangers of the regeneration system has been retained.

The end seals used in the new IPC are of a cellular type. The turbine is equipped with an electrohydraulic control system. The possibility of using the ejectors, low-pressure heaters, high-pressure heaters, and delivery-water heaters installed in the turbine unit that is subject to replacement will be decided after carrying out discussions with the customer and will be reflected in the technical specifications.

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